

MULTIPLE IGNEOUS BODIES FOR NAKHLITES AND CHASSIGNITES AS INFERRED FROM OLIVINE COOLING RATES USING CALCIUM ZONING.

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Introduction: Nakhlites and chassignites are ultramafic cumulate rocks of clinopyroxene and olivine, respectively, considered to have been formed in a thick lava flow or shallow intrusion near the Martian surface [e.g., 1,2]. Although more than 100 Martian meteorites have been found so far, most of them are shergottites and only nine nakhlites and three chassignites are known (considering paired samples) [3]. In contrast to shergottites which show large variations in both mineralogy and ages, nakhlites and chassignites are suggested to have been petrogenetically related, crystallized at about the same time and been ejected by the same impact event because of their identical crystallization (~1.3 Ga) and cosmic-ray exposure (10-11 My) ages [e.g., 1]. In this study we discuss the possibility of a common igneous body for all samples belonging to these two groups as suggested by previous studies [e.g., 4]. To do this we estimated cooling rates of olivine using Ca zoning profiles, especially by paying attention to the newest samples of each group (NWA 10720 nakhlite and NWA 8694 chassignite).

Results and Discussion: All nakhlites are mainly composed of cumulus augite and olivine, but show large variations in their mesostasis (or groundmass) abundances and their crystallinity. The groundmass abundance of NWA 998 and Lafayette is ~10 % and the groundmass is mostly composed of large single feldspar grains (~0.5 mm). In contrast, the mesostasis abundance reaches ~30 % in NWA 5790, MIL 03343 and NWA 817 and it is glassy, suggesting formation by fast cooling at the upper portion of the cumulus igneous body with large amounts of interstitial melt [e.g., 5]. The newest nakhlite NWA 10720 (paired with NWA 10153 [3]) has a similar high mesostasis abundance (~25 %), but it is well crystalline (lathy feldspar is 0.2-0.3 mm long). The estimated cooling rate of olivine in NWA 10720 using a Ca zoning profile from the core (0.5-0.6 wt% CaO) to the rim (0.1-0.2 wt% CaO) is ~100 °C/year (1100-700 °C) by assuming an originally constant Ca content. This cooling rate is identical to that of NWA 10153 [6], supporting their pairing and is comparable to those of Nakhla, Governador Valadares and Y000593 which have similar mesostasis crystallinity. The corresponding burial depth of this cooling rate is ~10 m [5]. The proposed nakhlite igneous body is suggested to exhibit stratigraphy having different cooling rates from the bottom to the top by accumulation of augite and olivine with interstitial evolving melt and all known nakhlite samples were located at different depths [e.g., 5]. NWA 10720 (and NWA 10153) does not fit well to this model, suggesting a separate igneous body for this particular sample in spite of the nearly identical crystallization age of NWA 10153 to other nakhlites [7]. This is consistent with its distinct Nd isotopic data [7]. Similarly, NWA 5790 is somewhat distinct from other samples in mineralogy and geochemistry and a separate flow or lobe separation was suggested [5,8].

Chassignites are cumulus dunites and three samples show distinct olivine compositions (Chassigny: Fo₆₉, NWA 2737: Fo₇₉, and NWA 8694: Fo₅₄). Olivine is homogeneous in Mg-Fe, but Ca shows a decrease towards the rims (core: 0.25 wt% CaO, rim: 0.1 wt% CaO), similar to nakhlite olivines except for lower Ca content at the core. The cooling rate estimate using Ca zoning of olivine gives nearly identical values (30-100 °C/year from 1100 to 700 °C, assuming initially homogeneous Ca content) for all three chassignites in spite of their different Fo contents [9,10]. Both low-Ca and high-Ca pyroxenes in all chassignites have fine exsolution textures (~0.1-1 µm lamella size), consistent with a fairly fast cooling rate suggested by the olivine zoning. Because olivine in three chassignites has similar cooling rates in spite of large variations of the Fo content, we suggest that each chassignite sample was derived from a separate igneous body although all chassignites could be petrogenetically related. Their distinct shock mineralogy also supports this hypothesis.

Conclusion: Thus, our study indicates multiple igneous bodies for nakhlites as well as for chassignites. Because chassignites and some nakhlites (e.g., Nakhla) have nearly identical cooling rates corresponding to 10-15 m burial depth in spite of different mineralogy, it is likely that nakhlites and chassignites did not share the same igneous body. However, we are not able to completely rule out the possibility that one common igneous body exhibited a large lateral heterogeneity in mineralogy and nakhlites and chassignites were located far from each other in horizontal distance.

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